STATIC FUMIGATION WITH PHOSPHINE IN LARGE ELEVATORS

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Abstract

Phosphine fumigation in silos during transfer from bin to bin involves energy loss, wear and tear of transport machinery, grain breakage and requires the availability of empty bins. In flat storage structures the problem is more acute due to uneven distribution of the phosphine tablets and slowness of the application.

Static fumigation trials were carried out in order to develop a more practical and economic method for fumigation with phosphine, and the efficiency of gas liberation and its rate of diffusion through the bulk were determined.

The trials were carried out between July 1984 and January 1985 in concrete bins 35.5 m high and 15 m diameter. They contained wheat and corn infested with Tribolium castaneum and Sitophilus oryzae. Pellets were distributed at the upper grain surface to obtain an overall dose rate of 1 g a.i. phosphine per ton.

The results very clearly demonstrated the efficient action of phosphine at the different depths of the bins. It was shown that the rates at which the gas penetrated to the bottom of the bins was different for wheat and corn. For static fumigation of each 4 800 ton capacity bin, a saving of the order of US$ 579 was calculated, exclusive of saving on reduction in breakage and full utilization of the bins.

Introduction

The increasing demand for storage space in Brazil, especially for storage of wheat, soybeans, rice and corn have stimulated the construction of large silos and grain storehouses with capacities ranging from ten thousand to a hundred thousand tons. The need for phytosanitary control measures in these installations was the reason for initiation of recent research studies.

The disadvantages of fumigating with phosphine during grain transfer from bin to bin, or when a bin is being loaded include handling problems, power waste, wear and tear of equipment, grain breakage, and in the case of flat warehouse storage, uneven tablet distribution and manpower problems when using probes.

Proc. 4th Int. Work Conf Stored-Product Protection, Tel Aviv, Israel, Sept 1986
[Eds E Donahaye and S Navarro], pp 519-527

A dearth of information on gas penetration and diffusion rates has restricted the use of fumigation with phosphine by more effective and cheaper means.

Some storage companies in their pursuit of better alternative fumigation procedures have used the aeration system to distribute the gas throughout the grain bulk or to introduce the tablets into the system. Not only does this practice result in partial loss of phosphine gas expelled to the outside air, but it is highly dangerous due to subsequent separation of phosphine from its protector gases (carbon dioxide and ammonia), (Greening, 1981), ingredients that prevent flammability of phosphine at high concentrations.

In some countries the aeration system is used as an aid to fumigation. In this case however, aeration is by closed recirculation to facilitate gas distribution, or is used to expel the fumigant from the bulk at the end of the fumigation period.

According to usual practice (instruction methods by German and local manufacturers), the pellets should be added to the grain during bulk transfer operations. In France, Buquet et al., (1978), recommend the use of automatic distributors for application to grain flow, while for static fumigations they recommend that the maximum height of the grain bulk be between 5 and 8 m to enable the probe to reach within one to two metres from the bin floor. In Australia, usual procedure is also by admixture during loading though it is known that in Newcastle CSIRO technicians obtained good penetration with surface application in airtight steel structures. In Germany, Degesch, the manufacturer of Phostoxin tablets recommends the tablets be incorporated into the commodity during loading, or through probes for static fumigation. If grain height does not exceed 3 m and air-tightness of the structure is good, tablets may be distributed over the surface of the commodity.

Thus three meters would appear to be the maximum distance of penetration through grain. Since most silos and granaries are from 10 to 35 m high, phosphine fumigation has traditionally been by grain transfer, while for flat storage, fumigation is by probes.

To determine the depth of effective action and speed of diffusion of phosphine (Gastoxin) through wheat and corn, experiments were initiated in the storehouse unit at Garibaldi (RS), owned by the Companhia Estadual de Silós e Armazens-CESA, Brazil. This silo is composed of five concrete bins with a total capacity of 25 000 tons.

Materials and Methods

The trials were carried out in bins with 16 cm thick walls, 15 m diameter, 35.5 m high (not including cone), and a capacity of about 5000 tons.

The first trial was undertaken in July 1984 in bin No.1 on 4 800 tons of corn at 13.2% moisture content (m.c.) and at 28°C, heavily infested with *Sitophilus oryzae* (L.) and *Tribolium castaneum* (Herbst). The second trial took place in bin No.2 containing 4 800 tons wheat at 13% m.c. and at 29°C, also infested with *S. oryzae*, and *T. castaneum*.

Seven holes, 1.25 cm diameter were drilled in the bin walls vertically from top to bottom (points 1-7, Fig.1). Special probes consisting of three 1 m units and enclosing 10 adults of *Sitophilus* and 10 adults of *Tribolium* were inserted into each hole. These additional artificial infestations served to evaluate fumigation efficiency at different heights during the 30 days of fumigation.

Filter paper imbibed with 10% silver nitrate and placed inside the tubes were used with a Drager unit to detect the presence of phosphine for evaluation of speed of penetration of the gas. In both trials phosphine was applied using 0.6 g pellets (0.2 g a.i. per pellet) at 5 pellets per ton. The pellets were placed in trays on the grain surface.

The headspace in bin No.1 containing corn (less than that containing wheat), was about 360 m^3. The maximum possible phosphine concentration (13 mg/liter) in the headspace was calculated beforehand to allow for a 50% safety margin below the lower explosion point of 27 mg/liter, (1.79% by volume).

Results and discussion

Complete mortality of both species of test insect was recorded in the wheat bin at points 1, 2, 3, 4, and 5 (up to 27 m depth) during 8 days of exposure. At points 6 and 7 gas concentrations were not detected even after 8 days when probes were removed, but replacement with new test insects and exposure at these points for a further 3 days resulted in 100% kill (Table 1).

For the corn fumigation complete mortality was recorded at all sampling points after 3 days exposure.

The wheat bin was kept sealed for 19.6 days (471 h) and the corn bin for 35.8 days (842 h). These prolonged exposure periods enabled the fumigant to affect developing stages of the insects.

Table 1: Percentage kill of S. oryzae and T. castaneum adults by phosphine fumigation in probes placed at different depths in wheat and corn bins.

	Wheat bin		Corn bin
Probe point No.	After 8 days Exposure	Reinfestation and after 3 days further exposure	After 3 days Exposure
1	100	-	100
2	100	-	100
3	100	-	100
4	100	-	100
5	100	-	100
6	0	100	100
7	0	100	100

During unloading (December 1984 - January 1985), grain samples taken from the two grain bulks were examined for survival of both immature and adult insects. Only one live psocid was recorded from these samples.

Despite the difficulty in controlling immature stages of Sitophilus by phosphine fumigation (Reynolds et. al., 1967), the mortalities obtained in these trials demonstrate the efficacy of the present procedure. In bin No.1 containing corn, gas diffusion was rapid due to the relatively large intergranular air-space. Within 17.1 h phosphine was recorded at point 7 (34.7 m). From the time the gas was detected at point 1 (4 m) 5 h after fumigant release, only 30 minutes elapsed before the gas was detected at point 4 at a depth of 20.5 m (Table 2). In analysis of gas penetration rate it should be noted that phosphine release starts two to three hours after exposure of the pellets to the air, and highest concentrations are reached after about 15 h.

In bin 2 containing wheat, gas diffusion was considerably slower than in the previous case. Point 7 at the bottom of the bin was reached in 166 h, a period 10 times longer than that required for the corn bin. Point 1 at 5 m was reached 14 h after fumigant application. Times for fumigant penetration between intermediate points were rather variable, minimum time being 6 h and maximum 49.3 h. Differences in gas penetration were probably due to accumulation of dockage in certain regions that hindered penetration and may have increased sorption of the gas thereby decreasing its concentration. According to Monro (1970), sorption is inversely correlated with temperature. However it is also true that diffusion is more rapid at high temperatures than at low ones.

Table 2: Time in hours for phosphine diffusion between consecutive sampling points in the fumigated corn and wheat bins

	Point No.						
	surface 1	2	3	4	5	6	7
Corn							
Distance (m)	4	5.5	5.5	5.5	5.5	5.5	4.5
Time (hours)	5	0.16	0.16	0.	3	7	1.40
Wheat							
Distance (m)	5	5.5	5.5	5.5	5.5	5.5	1
Time (hours)	14	25	6	32.3	49.3	6	33.3

The convection currents activated by temperature differences in the grain bulk are also partially responsible for upward and downward movement of phosphine through the grain bulk. The alternating appearance and disappearance of phosphine was recorded both during the downwards phase of gas penetration, and also after the maximum depth was reached. These fluctuations were less frequent for the wheat bulk, possibly due to its lower coefficient of porosity.

Cost analysis of a conventional fumigation involving grain transfer in comparison with a static fumigation is given in Table 3.

Table 3: Cost analysis of grain transfer operation (June 1984).

	Cr$	TOTAL
SERVICE COSTS/HOUR		
Electrical consumption	4 806	
Maintenance	564	5 370
STAFF COSTS/HOUR		
Wages and social benefits	3 525	
Bin administration	4 350	7 875
ESTIMATED COSTS/HOUR		
Equipment depreciation	2 166	2 166
SUBTOTAL		14 411
CENTRAL ADM. COST (30%)		4 623
TOTAL/HOUR		20 034
TOTAL FOR 50 HOUR FUMIGATION		1 001 700

Inclusive hourly costs of energy, maintenance, depreciation, staff and administration expenses, and cost/hour of grain turning at the Garibaldi silos was Cr$ 20 034 (US$ 11.59). Thus for a 50 h fumigation time required for a complete transfer of grain from one bin to another (at a nominal transfer rate of 100 tons/hour) the total cost (exclusive of fumigant material) was Cr$ 1 001 700 (US$579). This estimate does not include the fact that fumigation by grain transfer requires one bin of the silo to remain empty in order to receive the product. Since the Garibaldi silos consists of five 5 000 ton bins this means one fifth of the capacity, or 5 000 tons of storage capacity must remain empty for phosphine fumigation by the traditional method to be applicable.

Conclusions

Static fumigation with phosphine was carried out in air-tight, well sealed concrete silos 35.5 m high with the following results:

Complete mortality was obtained for all stages of *S. oryzae* and *T. castaneum* at a dose of 1 g phosphine a.i. per ton at the surface of a 4 800 ton corn bulk and wheat bulk.

There was a considerable difference in the time required for fumigant to penetrate to the bottom of the wheat and corn bins. The gas took 17.1 h to penetrate the corn column, and 166 h to penetrate the wheat column. The porosity of the commodity appears to be one of the major factors determining the rate of fumigant diffusion.

A cost reduction of Cr$ 1 001 700 (US$ 579) per unit fumigation was calculated for the Garibaldi silos, when the phosphine is applied by static fumigation.

References

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FIGURE N° 1

BINS DETAILS AND PHOSPHINE DIFFUSION SPEED IN CORN AND WHEAT

BIN 1 **CORN** | **BIN 2** **WHEAT**

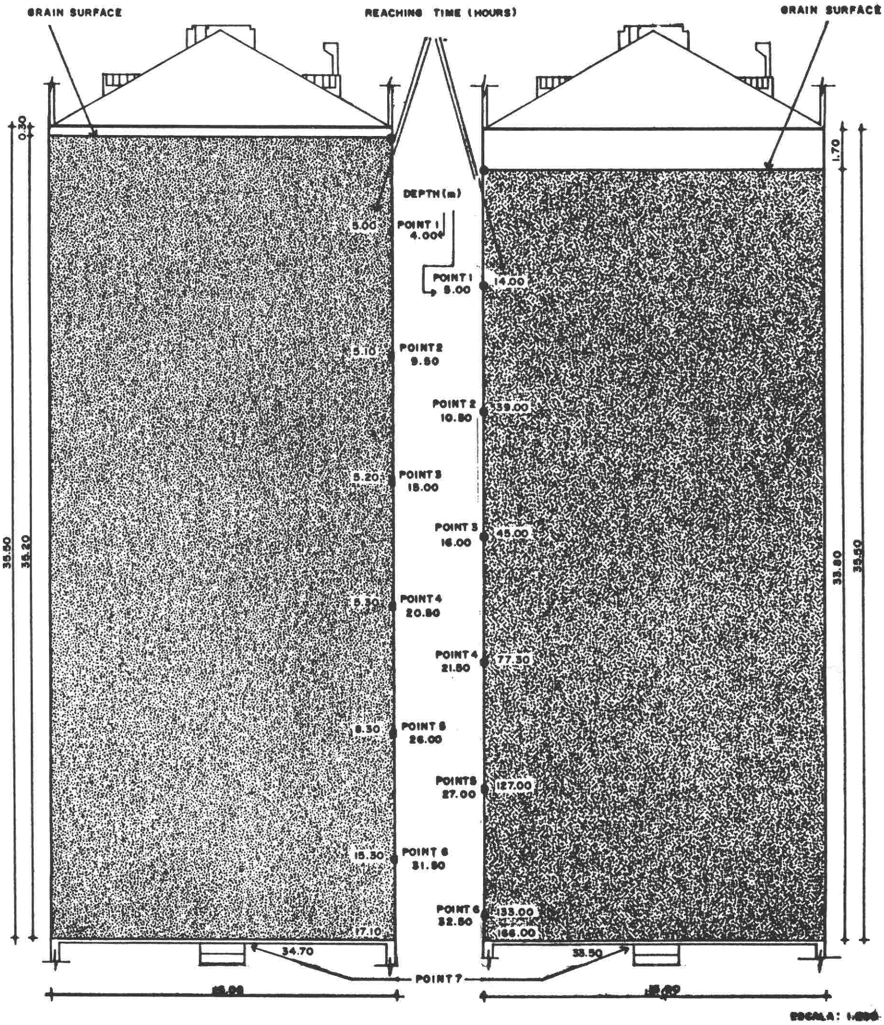


Fig. 2 **PHOSPHINE MOVEMENT INSIDE THE CORN BIN**

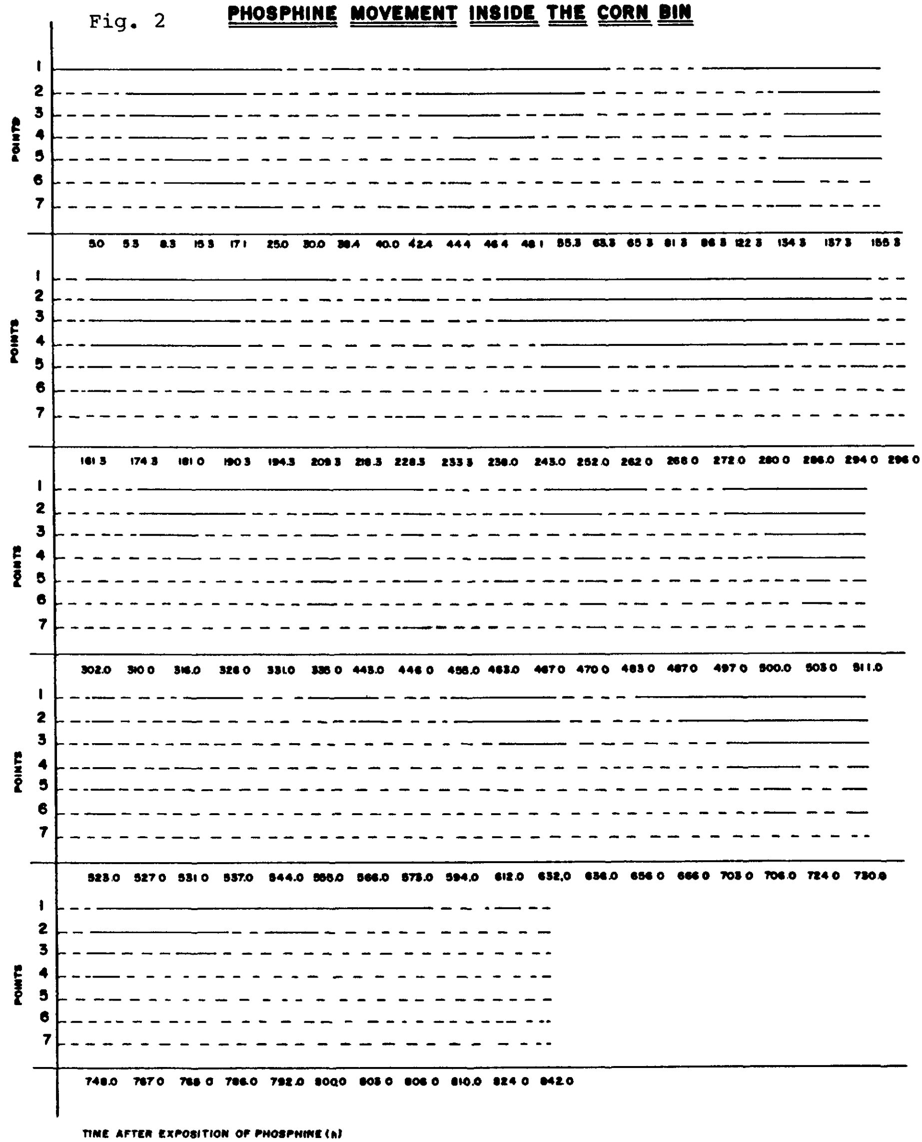
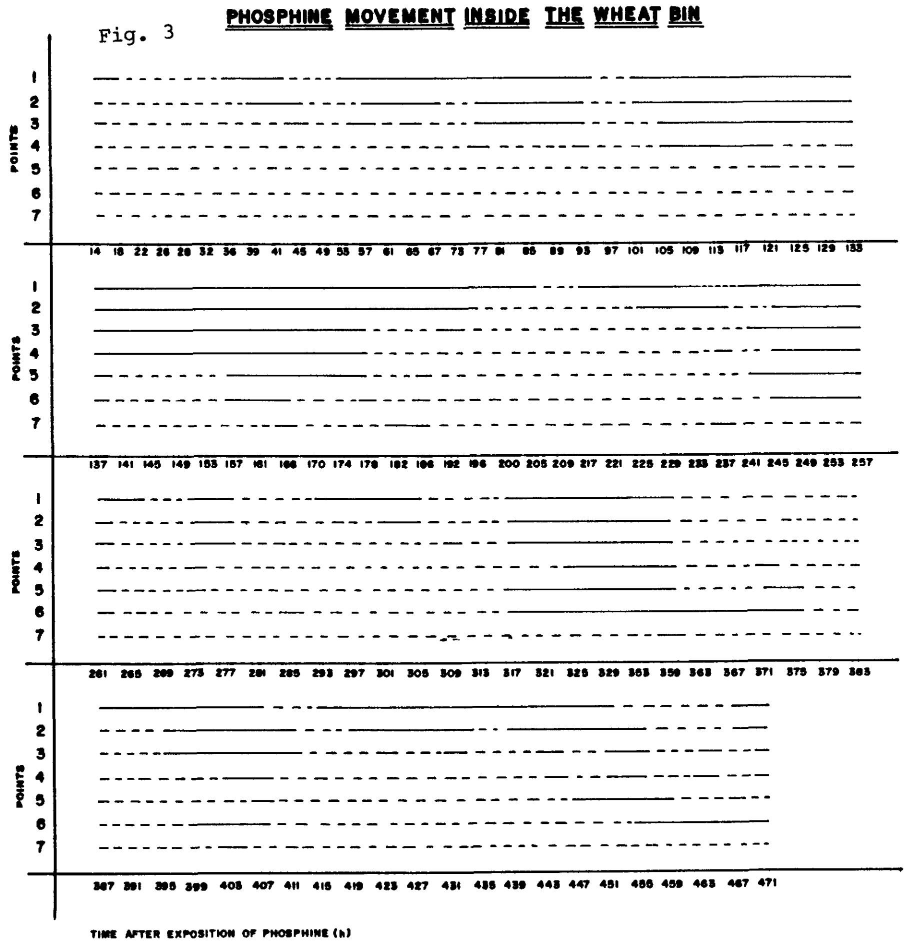


Fig. 3


PHOSPHINE MOVEMENT INSIDE THE WHEAT BIN
POINTS
TIME AFTER EXPOSITION OF PHOSPHINE (h)